

**CSCI 1377**

# **Tools for Thought**

# **Mnemonics II: Spaced Repetition Systems**

“I alone have more memories than  
all mankind since the world began.”

— Jorge Luis Borges, *Funes  
the Memorious* (1962)

- **What to expect for:**
  - **Lecture:** information dense, so no assigned readings → more time on assignments
    - Slides are more text-heavy than usual to offset lack of lecture notes or textbook
    - All cited works are linked from the website
  - **Assignments:** goal is hands-on: mixture of coding, data analysis, system analysis
  - **Midterm:** cover conceptual material (e.g. models of memory)
  - **Final project:** do something interesting related to course concepts!
- **Lecture etiquette**
  - Always come prepared to scribble, because I always try to incorporate interactive exercises into lecture
  - Only use laptops for note taking. Don't distract yourself or those around you.
  - Please keep voices down in the lobby after class to respect the administrative staff.

**Engaged retrieval spaced over  
time strengthens memory**

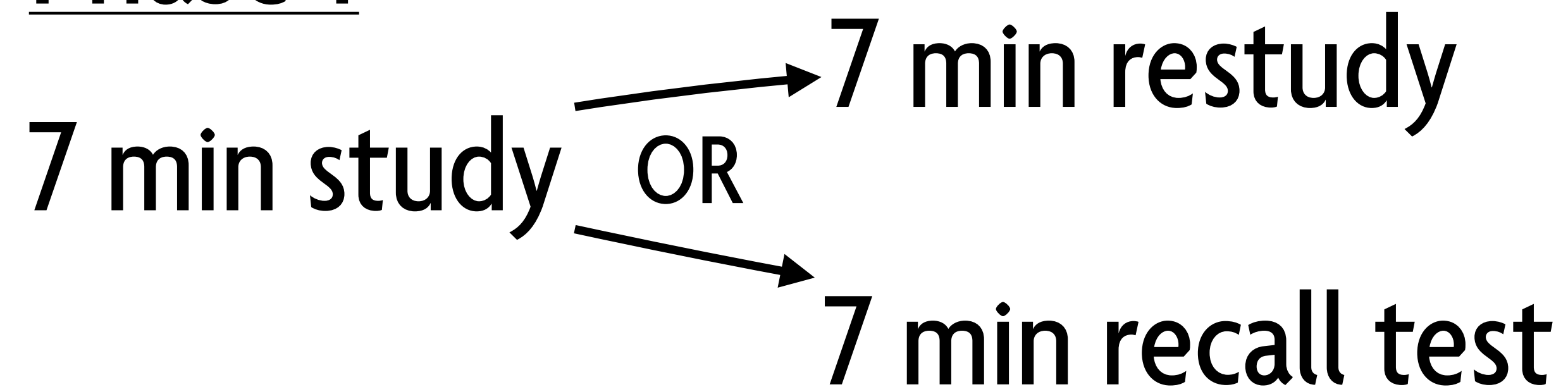
# Testing effect: tests improve recall over studying

## Materials: TOEFL exam passage

“Sea otters are a small mammal that lives in the waters along North America's west coast from California to Alaska. A few years ago some of the sea otter populations off of the Alaskan coast started to decline rapidly [...]”

## Procedure:

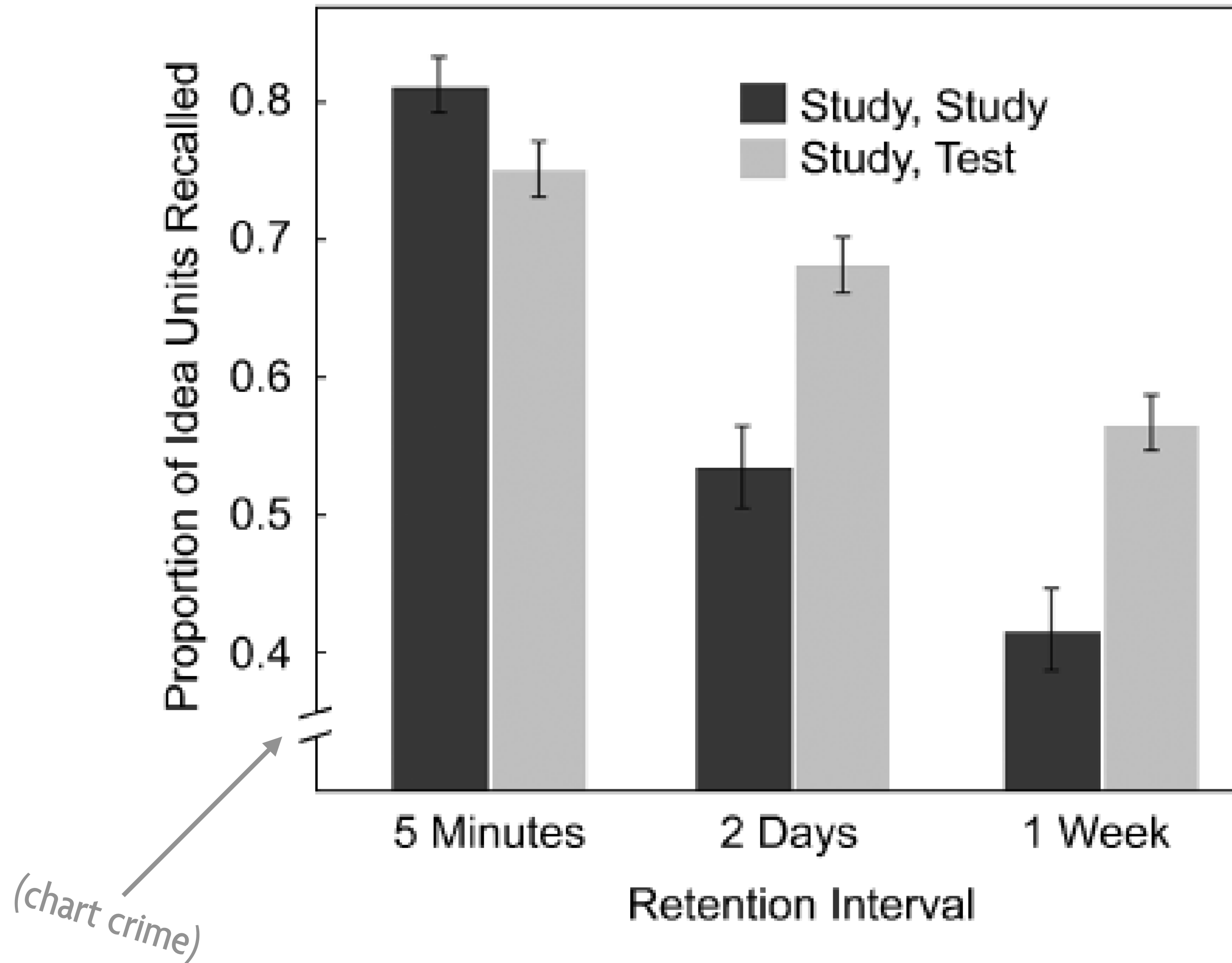
### Phase 1



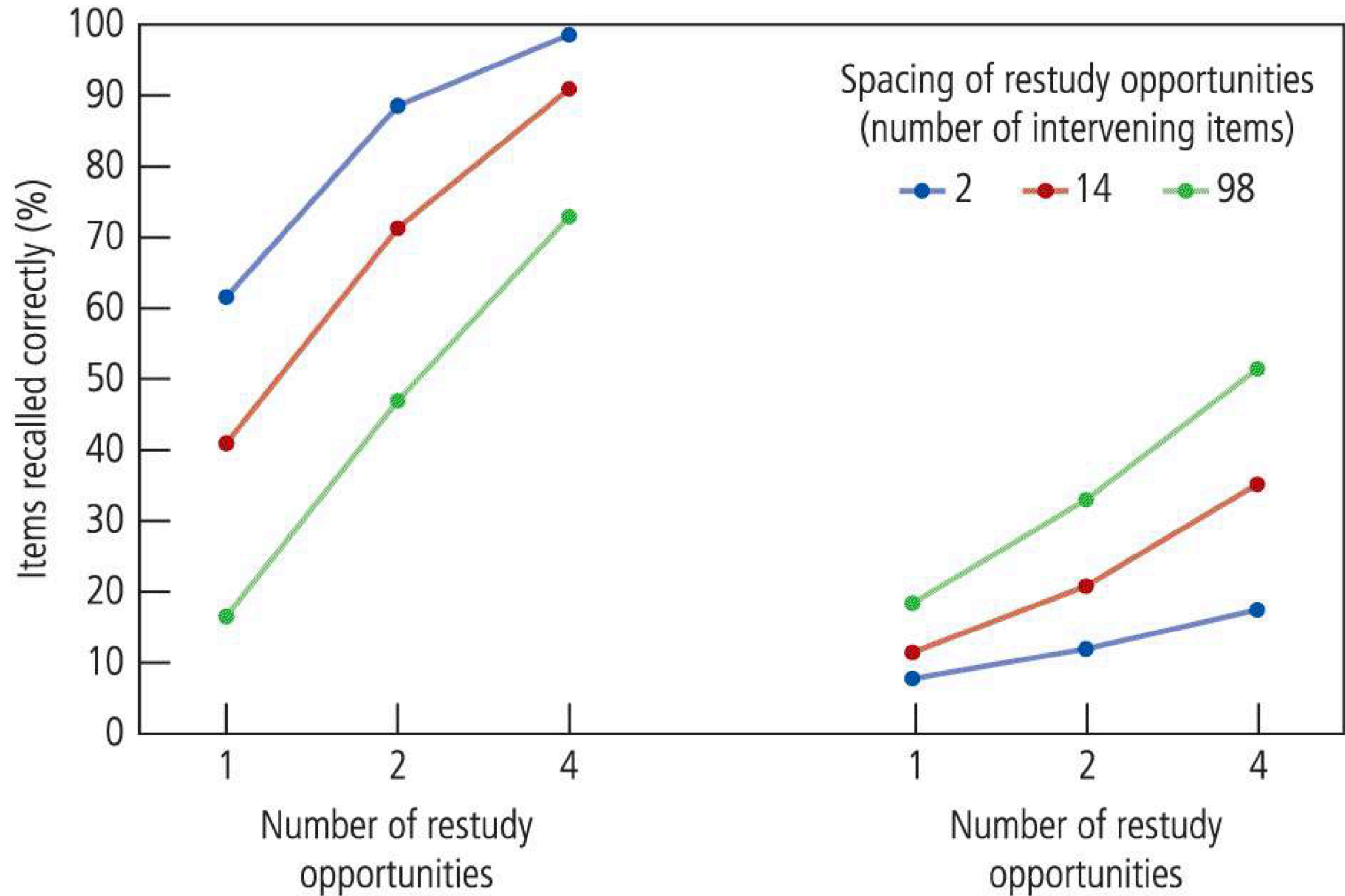
### Phase 2

Recall test after 5 min, 2 days, 1 week

# Testing effect: tests improve recall over studying



# Spacing effect: spacing improves retention



(a) Results of last test on first day

(b) Results of first test on next day

**Spaced repetition systems**  
**operationalize the**  
**testing & spacing effects**

# Primitives of an SRS: cards and decks

Card is a question + answer, deck is a collection of cards

说

---

请你再说一遍。

说

shuō

speak

verb

---

请你再说一遍。

Qǐng nǐ zài shuō yī biàn.

Sandhi: Qíng nǐ zài shuō yí biàn.

Can you please say it again.



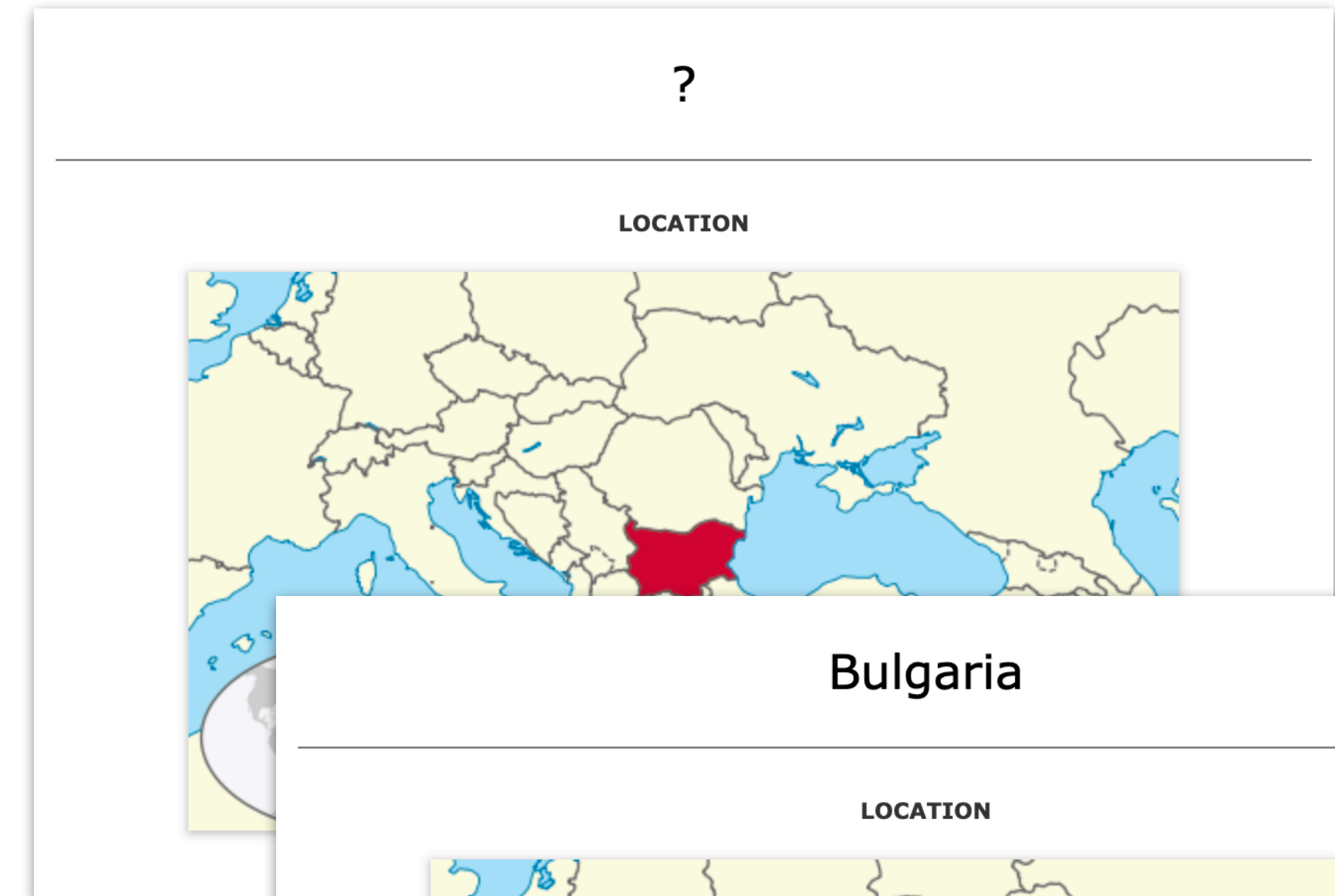
# Primitives of an SRS: cards and decks

Card is a question + answer, deck is a collection of cards

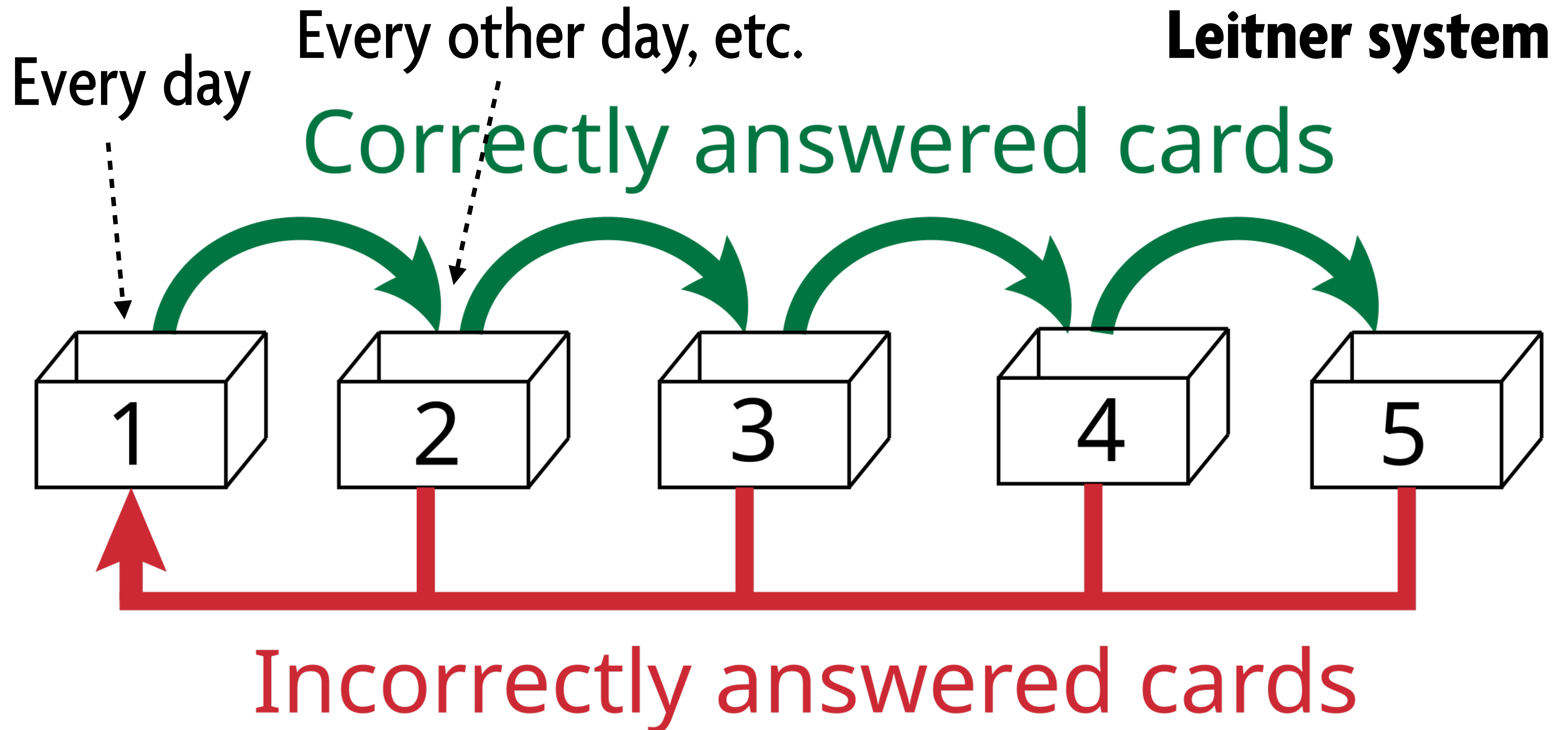
The Intrinsic apoptosis pathway ends with the activation of **[this caspase]**, the extrinsic pathway ends with the activation of **[this caspase]**, both initiator caspases converge into the common pathway by activating **[these two caspsases]**

The Intrinsic apoptosis pathway ends with the activation of **caspase-9**, the extrinsic pathway ends with the activation of **caspase-8**, both initiator caspases converge into the common pathway by activating **caspase 3 and 6 (executioner caspases)**

Big Robbins Page 56



# Primitives of an SRS: spacing algorithms



# Anki is the canonical modern SRS



Used by 86% of US med students [Ganjavi et al.]

+1 letter grade on med exams [Gilbert et al.]

Used by Jeopardy champions Roger Craig and Arthur Chu

# Standard use of SRS

- Find a deck
  - Shared decks on the internet, e.g., [ankiweb.net/shared/decks](https://ankiweb.net/shared/decks)
  - Create on your own deck manually or programmatically
    - Note: 50% of med students want to use AI to create cards! [Ganjavi et al.]
  - Use our deck!
- Review the SRS app every day
  - Configure # new cards per day based on time availability
- Repeat until memorious!

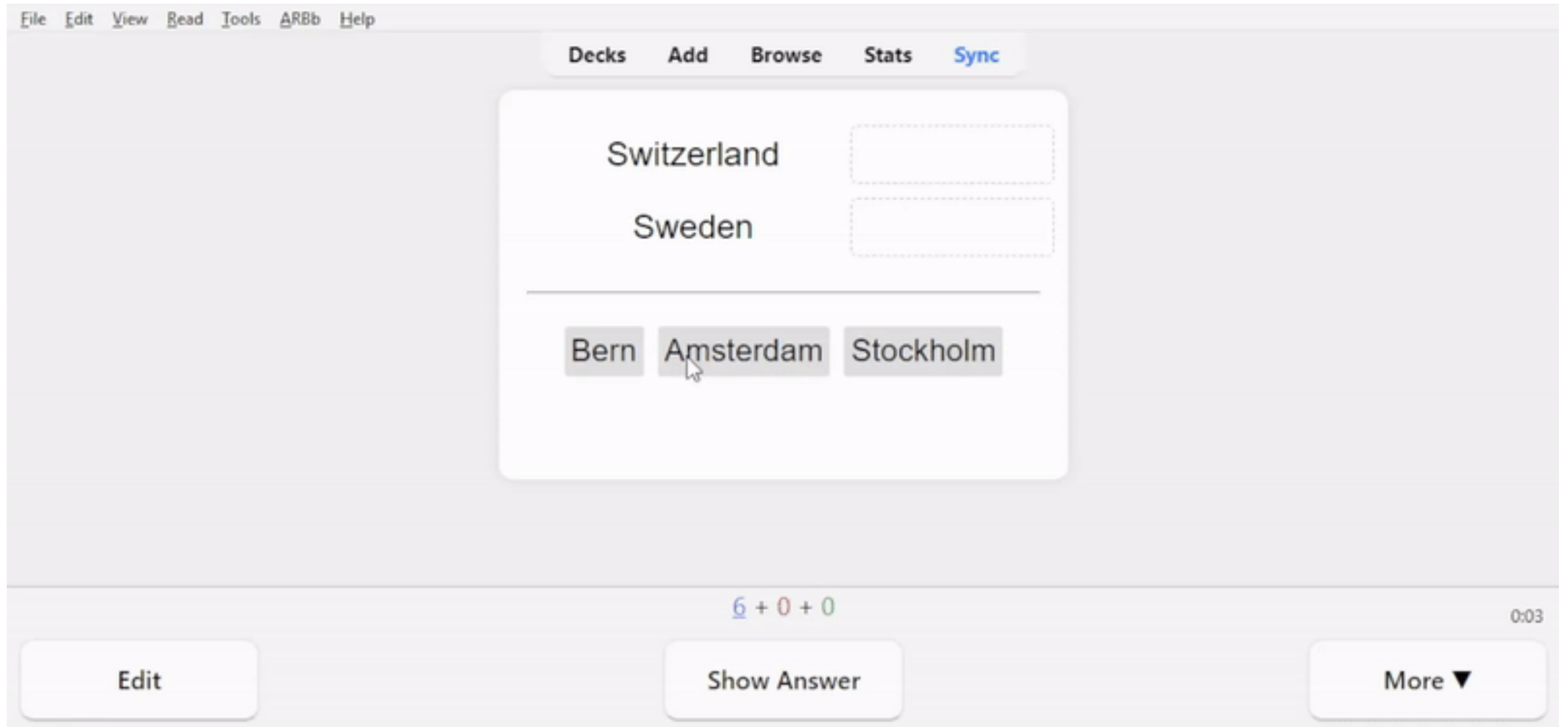
# When to use SRS?

- Gwern Branwen: “On average, when I’m studying a new topic, I’ll add 3–20 questions a day.”
  - “I find one of the best uses for [SRS] is, [...] to add in words from A Word a Day and Wiktionary, memorable quotes I see, personal information such as birthdays (or license plates, a problem for me before), and so on.”
- Michael Nielsen: “I find Anki a great help when reading research papers”
  - “What's the size of a Go board?”; “How many human game positions did AlphaGo learn from?”; “Where did AlphaGo get its training data?”
  - “I continued to add questions as I wrote my article, ending up adding several hundred questions in total”
  - “Part of developing Anki as a virtuoso skill is cultivating the ability to use it for types of understanding beyond basic facts.”

# Question formats can limit contrived memorization

Sweden - [ capital ] Switzerland - [ capital ]	Sweden - <u>Stockholm</u> Switzerland - <u>Bern</u>
Sweden - [ capital ] Switzerland - [ capital ]	Sweden - <u>Stockholm</u> Switzerland - <u>Bern</u>
Switzerland - [ capital ] Sweden - [ capital ]	Switzerland - <u>Bern</u> Sweden - <u>Stockholm</u>

# Question formats can limit contrived memorization



# **1. Integrating SRS into new contexts**

# Integrating SRS into an online textbook

In a many  
quantum  
qubit has  
of a qubit  
*dimension*  
here's a p

How many dimensions does the state space of a qubit have?

Click anywhere to reveal



Didn't remember



Remembered

enti  
qua  
e o  
y, th  
nce  
1  
0

How many dimensions does the state space of a qubit have?

2

in-text 1 week 3 weeks 3 months long-term



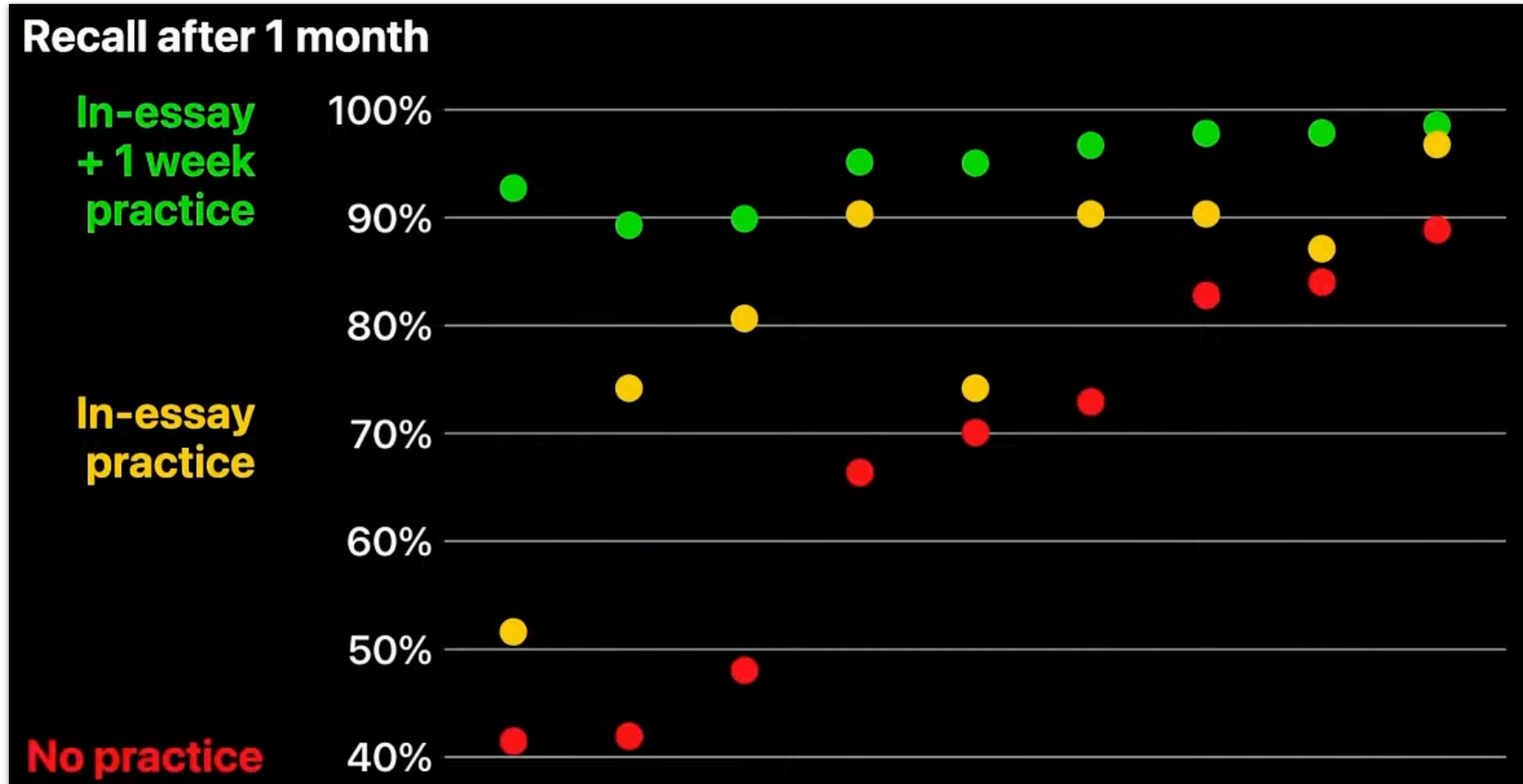
Didn't remember



Remembered

p of bits,  
a bit, a  
he state  
*a two-*  
stance,

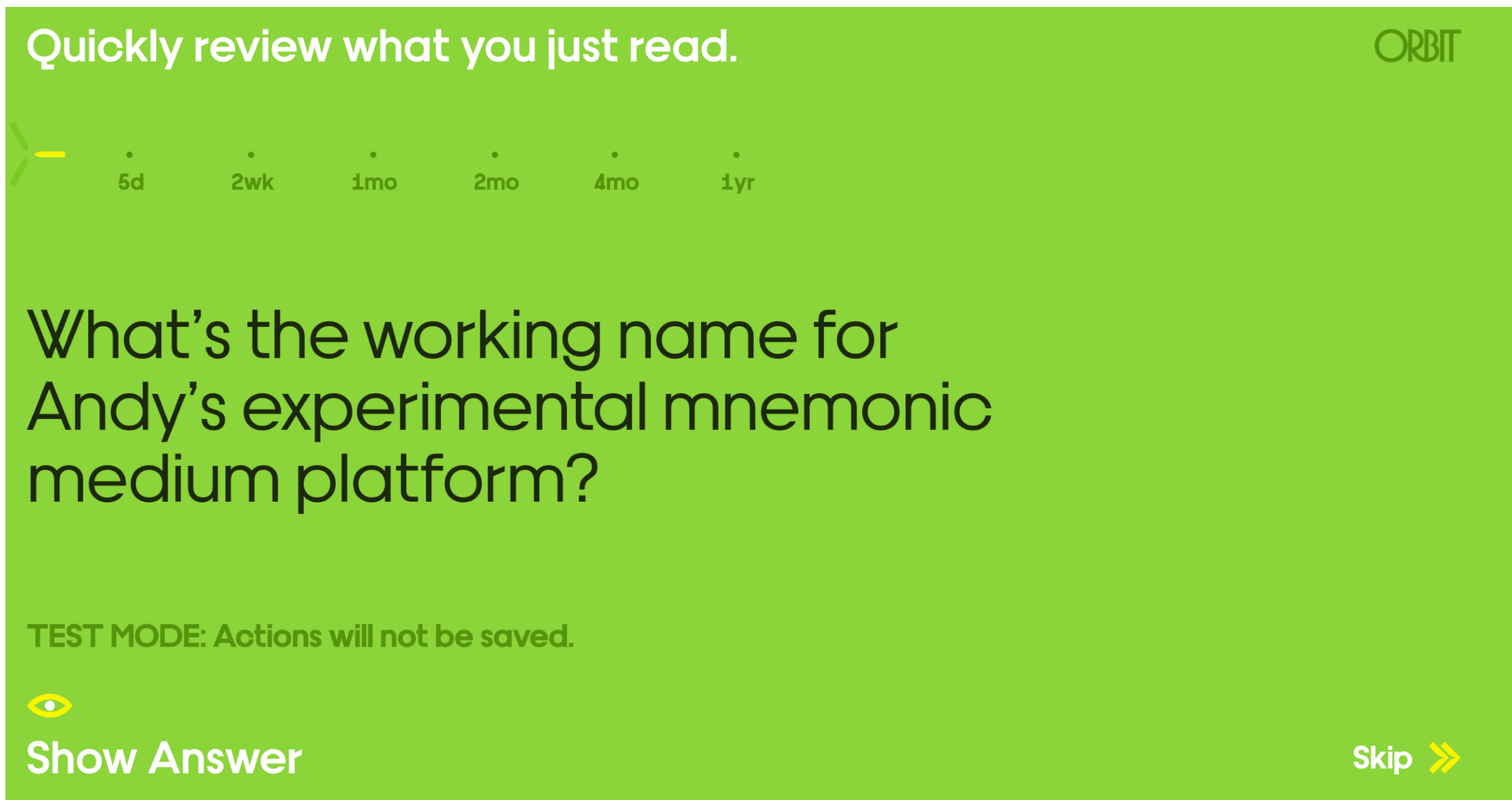
# Preliminary results show significant improvements



Question ID, sorted by difficulty

# Orbit: a platform for integrated SRS

```
<orbit-reviewarea color="lime">  
  <orbit-prompt  
    question="What's the working name for Andy's  
      experimental mnemonic medium platform?"  
    answer="Orbit"  
  ></orbit-prompt>  
</orbit-reviewarea>
```





Quickly review what you just read. ORBIT

5d 2wk 1mo 2mo 4mo 1yr

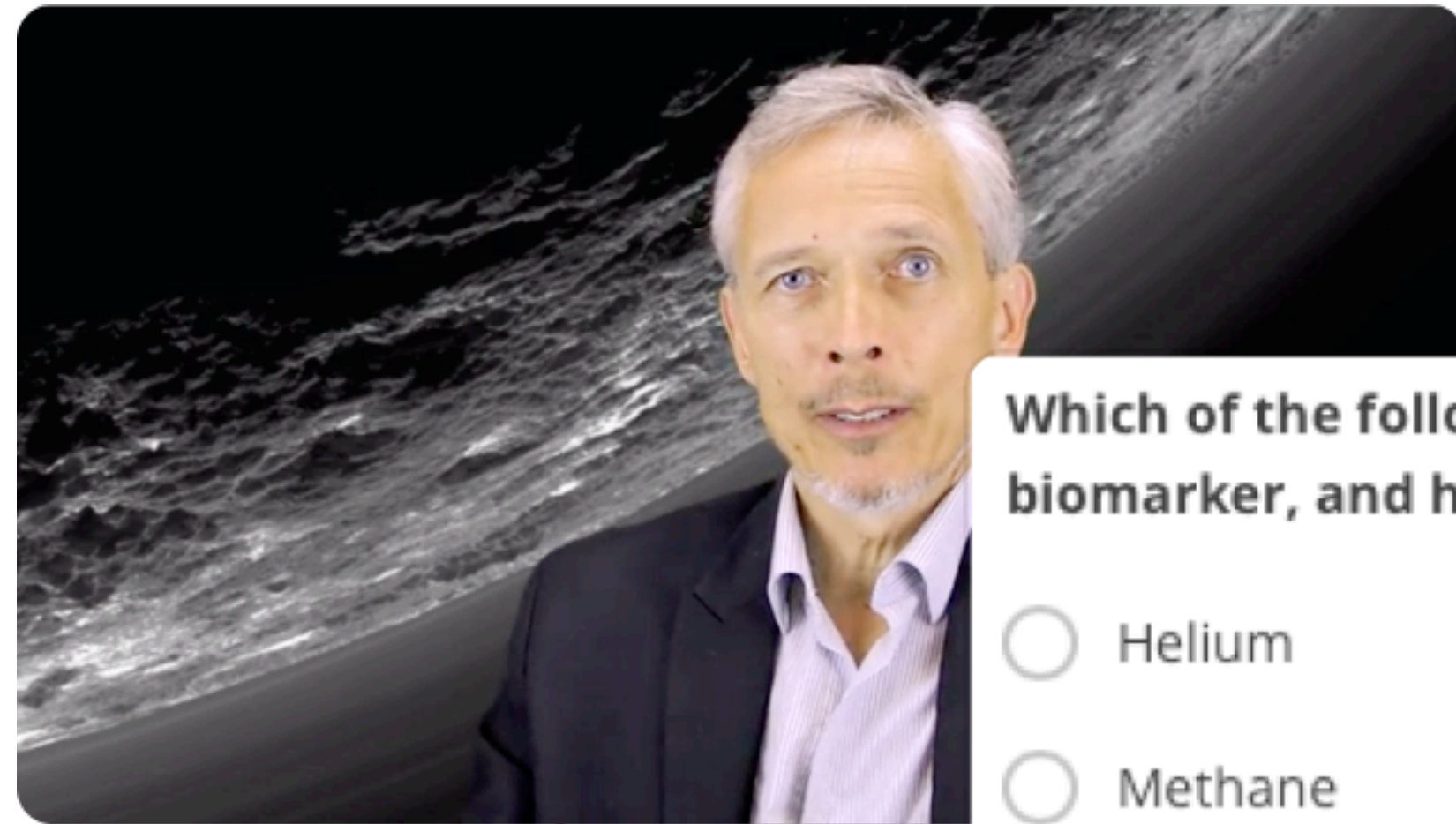
What's the working name for Andy's experimental mnemonic medium platform?

TEST MODE: Actions will not be saved.

 Show Answer

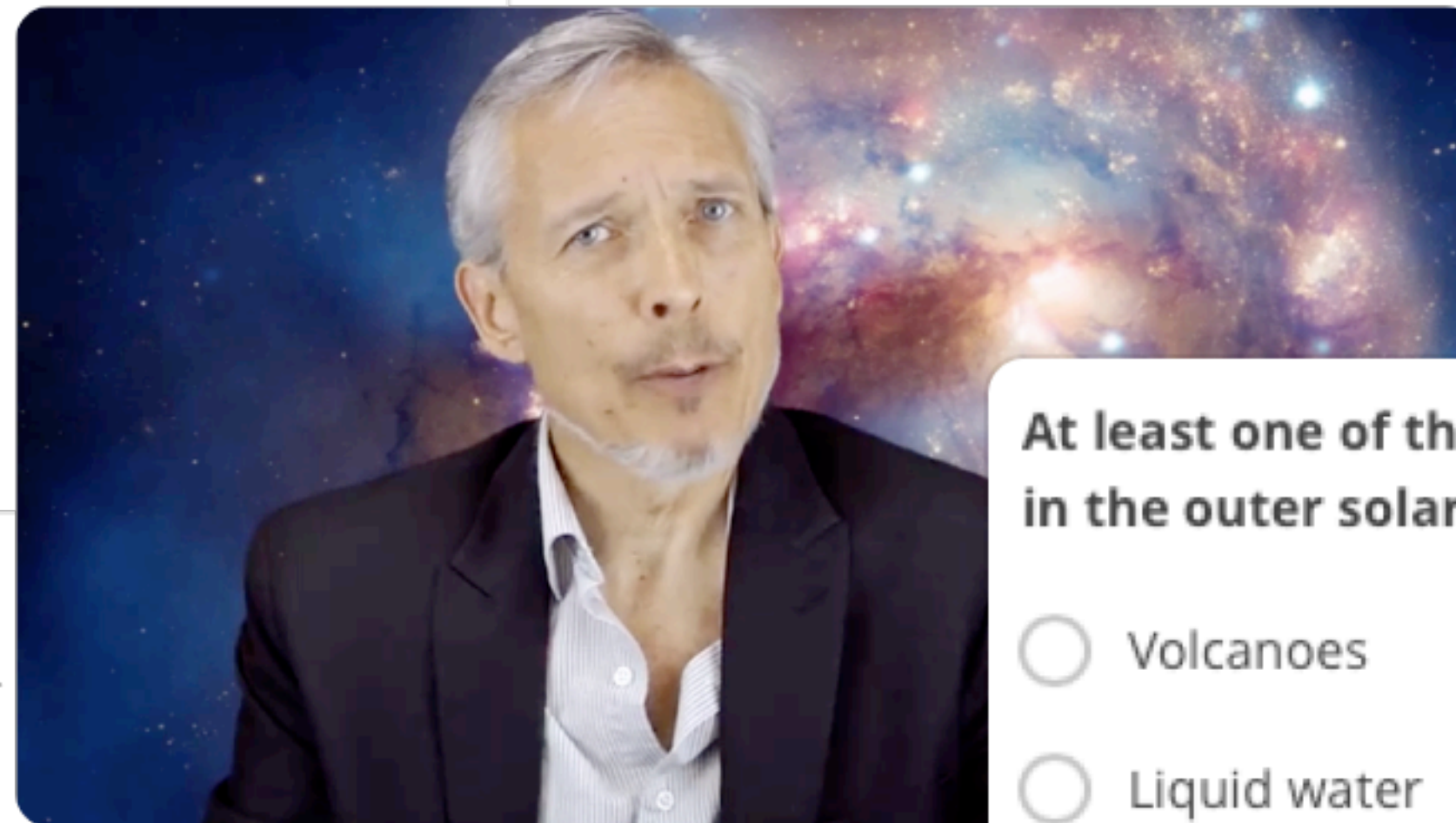
Skip 

# What would a mnemonic medium for video look like?



Which of the following greenhouse gases is also a biomarker, and has been found on Mars?

- Helium
- Methane
- Ozone
- Carbon Dioxide

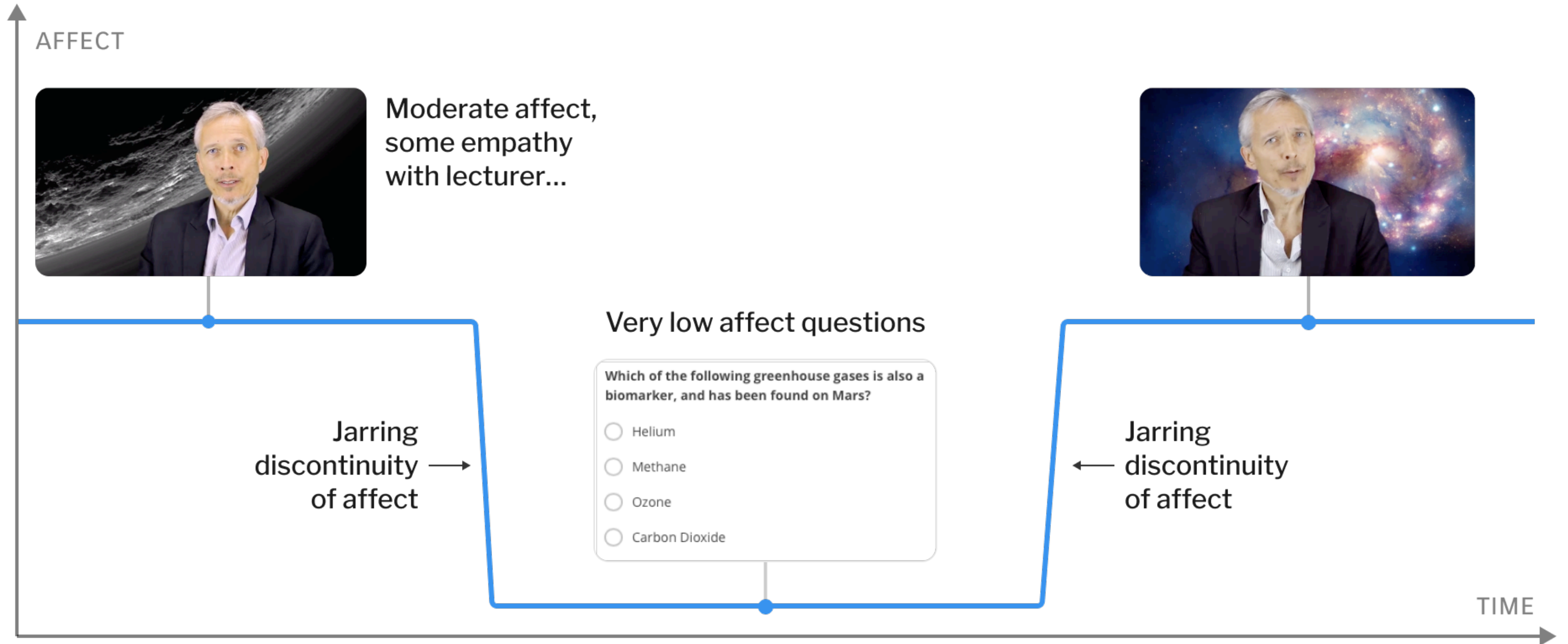


At least one of the moons orbiting the giant planets in the outer solar system have been found to have:

- Volcanoes
- Liquid water
- A thick atmosphere
- All of the above

From Coursera, “Astronomy: Exploring Time and Space.”

# What would a mnemonic medium for video look like?



# What would a mnemonic medium for video look like?

NARRATOR:

“In 1908, a piece of a comet hit the Earth. Hurling at more than 100,000 km/h, it was a mountain of ice the size of a football field and weighing almost a million tons.

If such an explosion happened today, it might be thought, in the panic of the moment, to be produced by a nuclear weapon.



**Dramatic visuals and narrative pathos establish high affect**

# What would a mnemonic medium for video look like?

“A cometary fragment will produce a great radiant fireball and a mighty blast wave. It’ll burn trees and level forests. Yet despite all that destruction, can you see why comets usually leave no crater in the ground?”



The narrator smoothly pivots to a question for the viewer, right in the middle of the video.

# What would a mnemonic medium for video look like?

*(no narration)*

The crater flyover and music continue while the viewer thinks...

We keep friction low to maintain immersion: the input is “tap anywhere.”

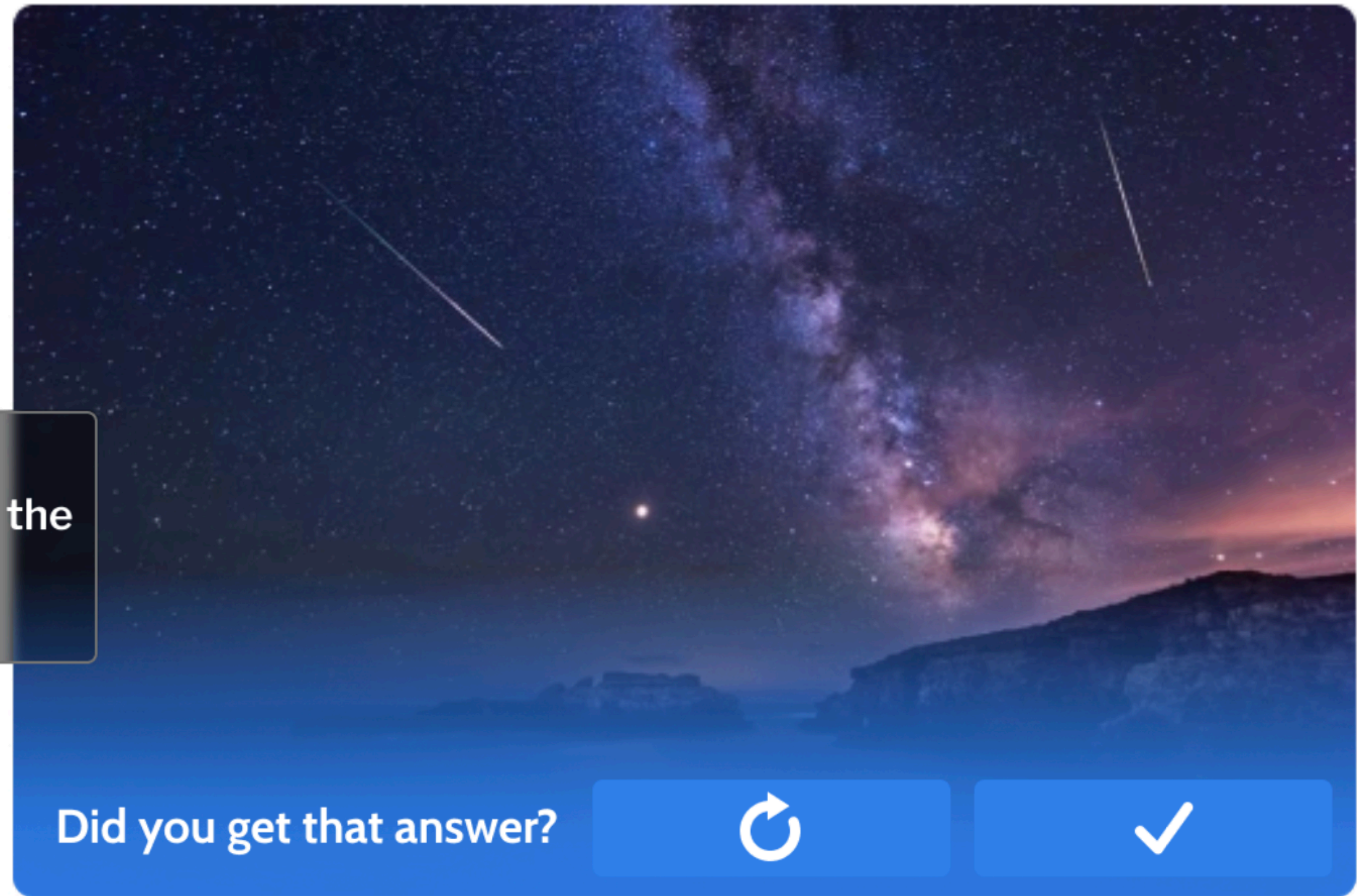
The question interface shares the screen with the video

Tap to hear the answer

# What would a mnemonic medium for video look like?

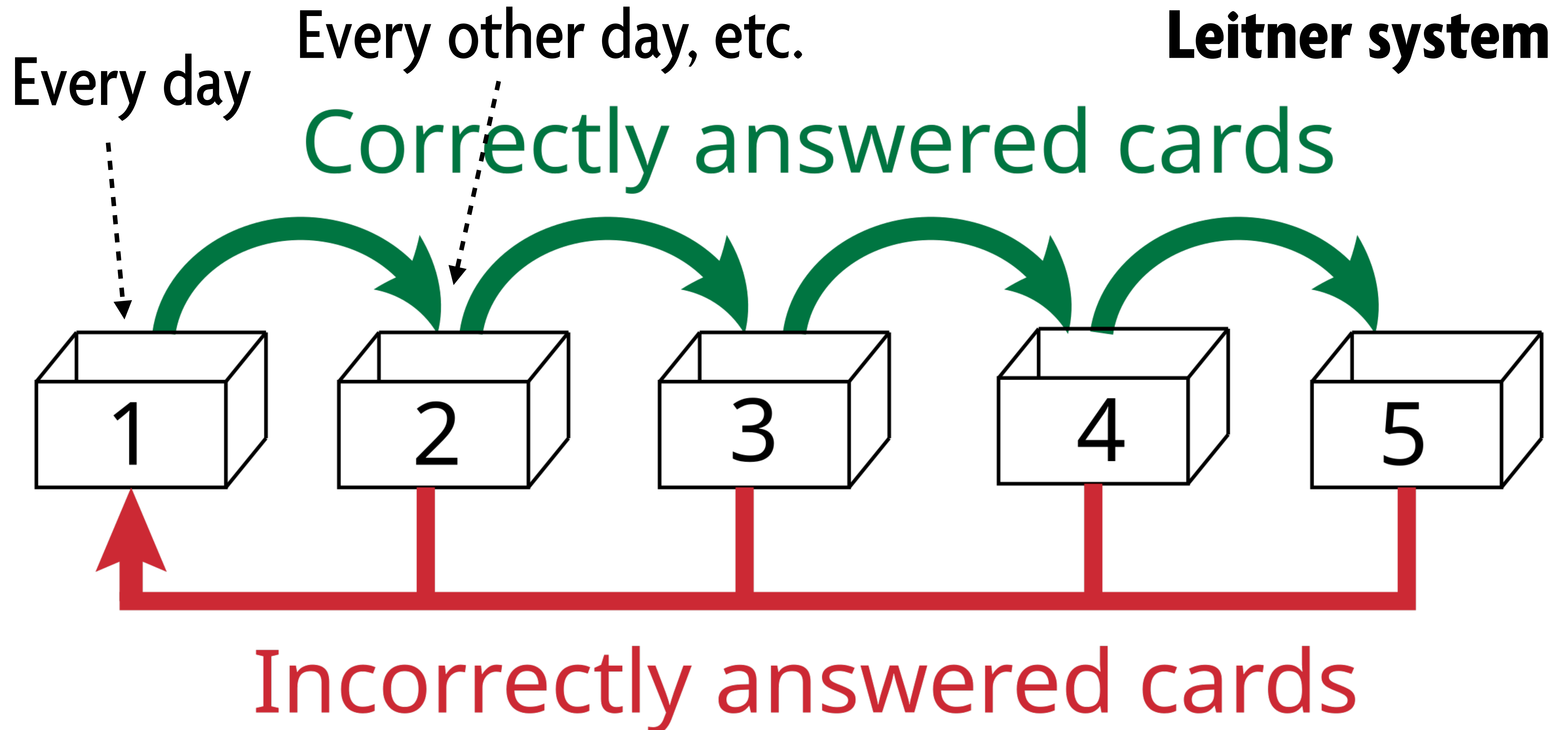
“We humans like to think of the heavens as stable, serene, unchanging. But comets suddenly appear and hang ominously in the sky, night after night, for weeks.”

The narrator continues onto other topics while the viewer marks whether they knew the answer



## **2. Designing new spacing algorithms**

# Primitives of an SRS: spacing algorithms

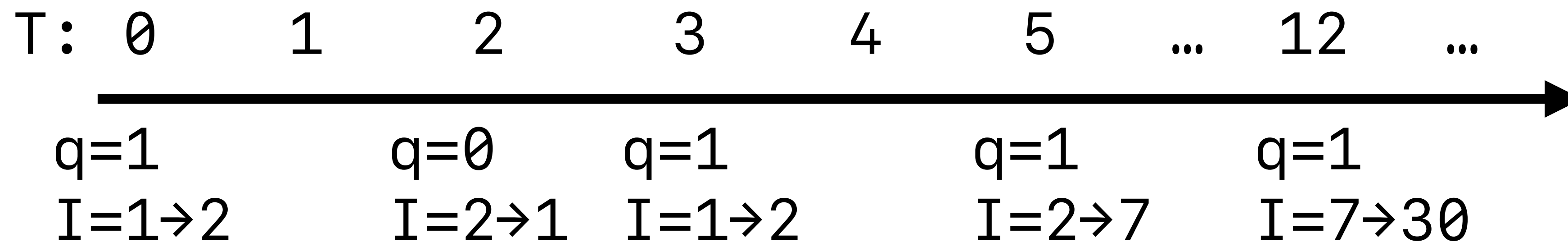


# Leitner spacing algorithm, roughly

**input:** user grade  $q$ ,  
interval  $I$

**output:** updated interval  $I$

```
if  $q = 1$  (correct) then
   $I \leftarrow$  case  $I$ 
    | 1  $\rightarrow$  2
    | 2  $\rightarrow$  7
    | 7  $\rightarrow$  30
    | 30  $\rightarrow$  365
else (incorrect)
   $I \leftarrow 0$ 
end
```



# Expanding spacing improved short-term recall over uniform or contracting spacing

## Materials:

12 names of fictitious people

Decks: 1 study card w/ 3 recall practice cards for each name

## Spacing:

- Uniform: 0,0,0 + 4,4,4 + 10,10,10
- Expanding: 0,3,10
- Contracting: 10,3,0

**Procedure:** practice deck → 30min distraction → recall test

## Example 0,3,10 deck

*Study:* Will Crichton

*Recall:* Will \_\_\_\_\_

*Study:* Jinho Lee

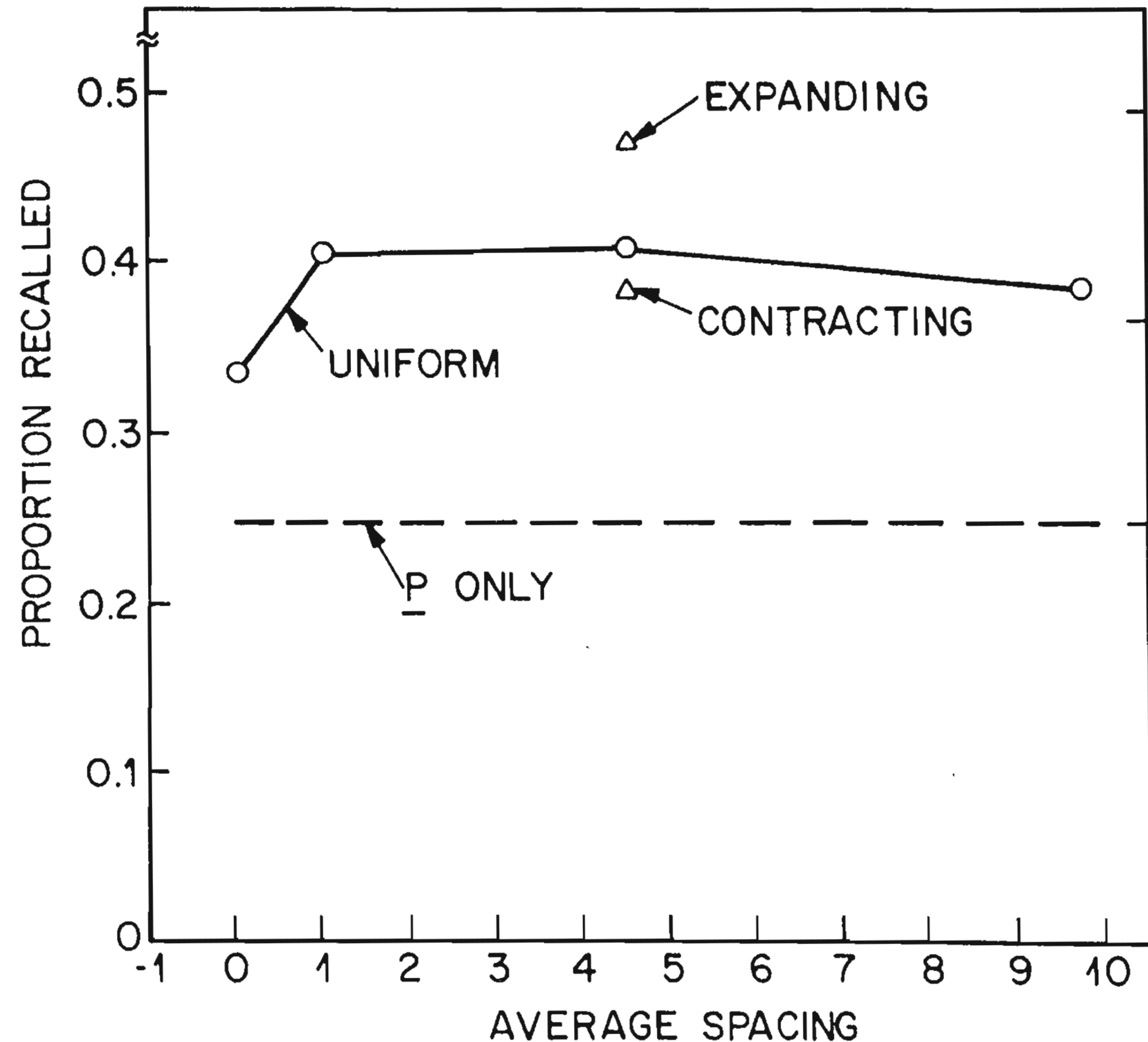
*Recall:* Jinho \_\_\_\_\_

*Study:* Eleanor Park

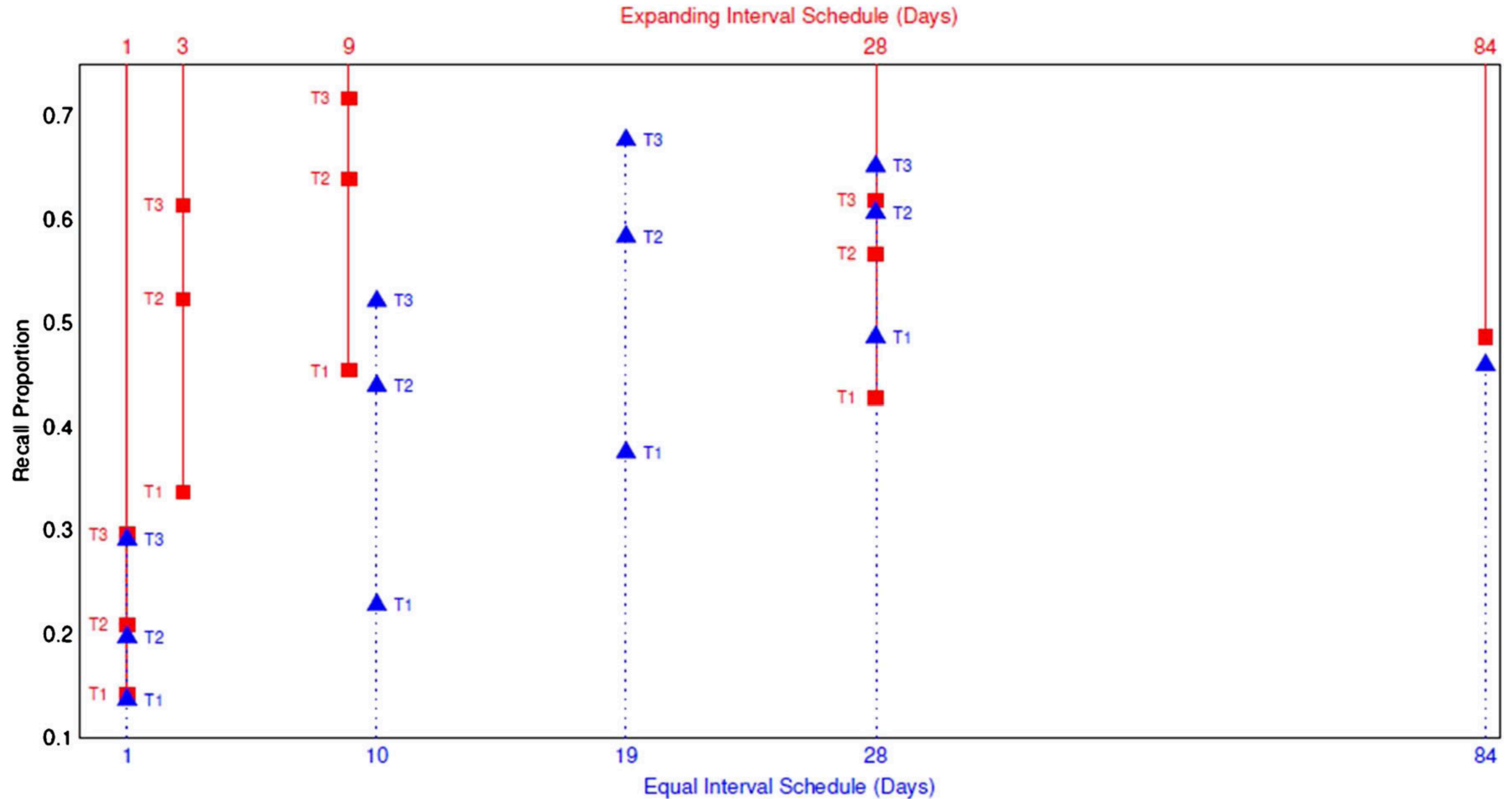
*Recall:* Will \_\_\_\_\_

*Recall:* Eleanor \_\_\_\_\_

# Expanding spacing improved short-term recall over uniform or contracting spacing



# Expanding spacing is not strictly better



# SuperMemo-2 (SM-2) algorithm

**input:** user grade  $q$ ,  
repetition number  $n$   
easiness factor  $EF$ ,  
interval  $I$

**output:** updated values of  
 $n$ ,  $EF$ , and  $I$

$q = 0$	complete blackout
1	incorrect, but hazy
2	incorrect, but close
3	correct with difficulty
4	correct with hesitation
5	perfect response

**adjust-easiness**( $EF$ ,  $q$ ):

$d \leftarrow 5 - q$

**return**  $\max(EF + 0.1 - 0.08d - 0.02d^2, 1.3)$

```
if  $q \geq 3$  (correct response)
then
   $I \leftarrow$  case  $n$ 
    | 0 => 1
    | 1 => 6
    | _ => round( $I \times EF$ )
   $n \leftarrow n + 1$ 
else (incorrect response)
   $I \leftarrow 1$ 
   $n \leftarrow 0$ 
end if
```

$EF \leftarrow$  **adjust-easiness**( $EF$ ,  $q$ )

# Example SM-2 trace for one card

<b>T</b>		$\emptyset$	1	...	7	...	22
<b>q</b>		3	5		4		1
<b>n</b>	$\emptyset$	1	2		3		$\emptyset$
<b>I</b>	1	1	6		15		1
<b>EF</b>	2.50	2.36	2.46		2.46		1.92